

U.S. DEPARTMENT OF COMMERCE, PATENT AND TRADEMARK OFFICE		DATE: January 14, 2002
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EQ/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S. APPLN. NO. (if known): 107030087
INTERNATIONAL APPLICATION NO.: PCT/JP00/04744	INTERNATIONAL FILING DATE: JULY 14, 2000	PRIORITY DATE CLAIMED: JULY 14, 1999
TITLE OF INVENTION: BEAM SOURCE		
APPLICANT(S) FOR DO/EQ/US: Masahiro HATAKEYAMA, Katsunori ICHIKI, Kenji WATANABE and Tohru SATAKE		
Applicant hereby submits to the United States Designated/Elected Office (DO/EQ/US) the following items and other information:		
<p>1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.</p> <p>2. <input type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.</p> <p>3. <input checked="" type="checkbox"/> This express request to begin national examination procedures (35 USC 371(f)) at any time rather than delay examination until the expiration of the time limit set in 35 USC 371(b) and PCT Articles 22 and 39(1).</p> <p>4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.</p> <p>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2)):</p> <p>a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US)</p> <p>6. <input checked="" type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)).</p> <p>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))</p> <p>a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input type="checkbox"/> have been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</p> <p>d. <input checked="" type="checkbox"/> have not been made and will not be made.</p> <p>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</p> <p>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</p> <p>10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</p> <p>ITEMS 11. TO 16. BELOW CONCERN OTHER DOCUMENT(S) OR INFORMATION INCLUDED:</p> <p>11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98 together with the international search report and 6 references.</p> <p>12. <input checked="" type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. ASSIGNEE NAME AND ADDRESS: EBARA CORPORATION, Tokyo, Japan Please publish the assignee data with the application.</p> <p>13. <input type="checkbox"/> A FIRST preliminary amendment. <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment</p> <p>14. <input type="checkbox"/> A substitute specification.</p> <p>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</p> <p>16. <input checked="" type="checkbox"/> Other items or information: 7 sheets of drawings.</p>		

U.S. APPLICATION NO. (if known) 10/030087	INTERNATIONAL APPLICATION NO. PCT/JP00/04744	DATE: January 14, 2002	
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17. <input checked="" type="checkbox"/> The following fees are submitted: Basic National Fee (37 CFR 1.492(a)(1)-(5): Search Report has been prepared by the EPO or JPO: \$890.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) \$710.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) \$740.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$1040.00 International preliminary examination fee (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) \$100.00 <div style="text-align: right;">ENTER APPROPRIATE BASIC FEE AMOUNT = \$ 890.00</div>	CALCULATIONS	PTO USE ONLY
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Surcharge of \$130.00 for furnishing the oath or declaration later than <u> 20 </u> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).		
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CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
TOTAL	5 - 20 =		X \$ 18.00		
INDEPENDENT	1 - 3 =		X \$ 84.00		
Multiple dependent claims(s) (if applicable)			+ \$280.00		
TOTAL OF ABOVE CALCULATIONS =				\$ 890.00	

Reduction by 1/2 for filing by small entity, if applicable. (Note 37 CFR 1.9, 1.27, 1.28).		
SUBTOTAL =		\$ 890.00

Processing fee of \$130.00 for furnishing the English translation later than <u> 20 </u> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).		
TOTAL NATIONAL FEE =		\$ 890.00

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +		
TOTAL FEES ENCLOSED =		\$ 930.00

	Amount to be:	
	refunded	\$ _____
	charged	\$ _____

U.S. APPLICATION NO. (if known) 10/030087	INTERNATIONAL APPLICATION NO. PCT/JP00/04744	DATE: January 14, 2002
<p>a. <input checked="" type="checkbox"/> A check in the amount of \$930.00 to cover the above fees is enclosed. (\$890.00 for basic filing fee and \$40.00 for assignment recordation fee). (This paper is filed in triplicate)</p> <p>b. <input type="checkbox"/> Please charge my Deposit Account No. 01-2340 in the amount of \$_____ to cover the above fees. (A duplicate copy of this sheet is enclosed.)</p> <p>c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 01-2340.</p> <p>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed to request that the application be restored to pending status.</p> <p>Send All Correspondence To:</p> <div style="text-align: center;"> 23850 PATENT TRADEMARK OFFICE</div> <div style="text-align: right;"> SIGNATURE Mel R. Quintos NAME 31,898 REGISTRATION NUMBER</div>		

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DESCRIPTION

BEAM SOURCE

Technical Field

- 5 The present invention relates to a beam source for generating a high-density ion beam, neutral particle beam, or the like having good directivity from high-density plasma.

Background Art

- 10 In recent years, there has been a remarkable reduction in the size of processing patterns used in semiconductor ICs, data storage media including hard disks, micro-machines, and other fields. Processing technologies, such as deposition and etching, used in these fields now require relatively broad irradiating
- 15 energy beams such as high-density neutral particle beams or ion beams having high collimation (good directivity). The inventors of the present invention and others have already disclosed beam sources having the following constructions for such applications.

- 20 The first type of beam source comprises a discharge tube, a gas feed nozzle disposed upstream from the discharge tube for supplying gas therein, a beam-emitting electrode formed with a plurality of apertures and disposed on the downstream end of the discharge tube, and a plurality of electrodes disposed within
- 25 the discharge tube. By applying a combination of different voltages to these electrodes, including a radio-frequency (RF) voltage, direct-current voltage, and ground voltage and by varying the type of gas introduced into the discharge tube, the

beam source can generate different energy-level beams of differing types, such as positive ions, negative ions, neutral particles, radicals, and the like. A beam source of this construction is relatively compact and can be mounted on a manipulator to irradiate a beam onto a desired target in order to perform such localized processes on the target as deposition, etching, adhesion, bonding, and the like.

The second beam source is configured as the first with a nozzle disposed upstream from a cylindrical discharge tube for introducing gas therein, and a beam-emitting electrode (cathode) disposed downstream and formed with a plurality of apertures. This beam source also comprises an anode disposed in the discharge tube on the upstream end, a mechanism for applying a DC voltage across the anode and cathode, and an inductively coupled plasma-generating mechanism for converting gas in the discharge tube between these electrodes into plasma. A neutral particle beam source having this construction can generate high-density plasma from gas introduced into the discharge tube according to the inductively coupled high-frequency plasma-generating mechanism and can accelerate positive ions in the plasma on the cathode side using the two parallel electrodes. Charge exchange takes place in high-speed atom emission holes formed in the cathode on the downstream end, resulting in the emission of a neutral particle beam.

Unlike the above-described direct-current discharge beam source, this neutral particle beam source is provided with a plasma-generating section and an accelerating voltage section capable of generating high-density plasma at a low energy. Since

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a desired voltage from a low to a high voltage can be applied across the two electrodes, the beam source can generate a neutral particle beam at a desired energy level from a low energy to a high energy. Since the anode and cathode are disposed parallel to each other it is possible to generate a neutral particle beam with good directivity (collimation) and having a relatively high neutralization rate by controlling the length of the high-speed atom emission holes.

However, the above-described beam sources have not always been sufficient for forming high-density plasma and for efficiently extracting from this plasma an energy beam, such as an ion beam or neutral particle beam, having high directivity and high density.

Disclosure of Invention

In view of the foregoing, it is an object of the present invention to provide a beam source capable of efficiently generating a high-density energy beam having good directivity and a relatively large beam diameter.

These objects and others will be attained by a beam source comprising a discharge tube; a gas inlet for introducing gas into the discharge tube; three electrodes mounted in the discharge tube downstream from the gas inlet, wherein the electrode on the upstream end has a plurality of openings through which the gas can pass, the middle electrode is a mesh-shaped electrode, and the electrode on the downstream end is a beam-emitting electrode having a plurality of beam-emitting holes and is disposed in a plane parallel to the middle electrode; plasma-generating means

disposed between the two upstream electrodes on the outside of the discharge tube for transforming gas introduced into the discharge tube into plasma; and voltage-applying means for accelerating the beam between the two downstream electrodes and emitting the accelerated beam from the downstream beam-emitting electrode.

The present invention has a plasma-generating means for forming high-density plasma from gas introduced into the discharge tube between the two upstream electrodes. Since the middle electrode is a thin mesh-type electrode having a plurality of openings, high-density plasma formed on the upstream side of this electrode is efficiently introduced between the two electrodes on the downstream end. The two downstream electrodes are parallel to each other, and a voltage is applied thereacross to accelerate the charged particles. These accelerated particles are emitted through the electrode disposed on the downstream end of the discharge tube that is formed with a plurality of beam emitting holes. Accordingly, an ion beam is efficiently extracted from the high-density plasma, generating a highly ionized and relatively broad beam having good directivity.

Further, the two electrodes on the upstream end have the same potential, while the beam-emitting electrode on the downstream end has the same potential as that of a chamber into which the beam is emitted.

Setting the two upstream electrodes at the same potential stabilizes the potential of plasma formed therebetween, enabling the potential to be controlled as desired. Further, since the

potential of the downstream electrode is the same as that of the chamber into which plasma is discharged, it is possible to emit ions accelerated between the two downstream electrodes as an energy beam, such as an ion beam or a neutral particle beam, into the chamber.

Further, the mesh electrode is formed of a conductive material in a thin plate shape and has a plurality of openings. The open area ratio of the electrode should be 85% or less. Accordingly, a charged particle beam can be easily formed from the high-density plasma between the two downstream electrodes with a relatively short sheath length.

Further, the two electrodes on the downstream end are separated by a distance of 5 millimeters or greater, and preferably by a distance of 10-30 millimeters. Accordingly, a relatively low-energy beam appropriate for micro-fabrication can be efficiently extracted from the high-density plasma.

Further, each of the beam-emitting holes formed in the beam-emitting electrode on the downstream end has a length-to-diameter ratio of 2 or greater. Accordingly, the accelerated beam between the two downstream electrodes can be emitted without loss of directivity or density.

Further, the voltage-applying means applies a positive-negative pulse-type voltage that alternately irradiates either positive ions and negative ions or positive ions and electrons. Accordingly, by alternately irradiating positive ions and negative ions (or electrons), high-precision etching and deposition processes can be conducted while reducing the amount of charge buildup on the surfaces of insulating

materials, such as glass and ceramic materials.

Brief Description of Drawings

FIG. 1 is an explanatory diagram showing the overall
5 configuration of a micro-fabrication apparatus employing a beam
source;

FIG. 2 is a perspective view showing the construction of
a beam source according to a first embodiment of the present
invention;

10 FIG. 3 is a graph showing the relationship between electron
density of plasma and sheath length;

FIG. 4 shows example configurations of a mesh electrode,
including a thin metal plate formed with square openings in FIG.
4A, a metal wiring woven into a mesh shape in FIG. 4B, and a thin
15 plate constructed from a conductive material such as silicon or
graphite and formed with circular openings.

FIG. 5 is an explanatory diagram showing the effect of mesh
open area ratio on the processed shape of the irradiated object;

FIG. 6 is a graph showing the relationship between the
20 distance between the mesh electrode and beam-emitting electrode
and the processing speed of the irradiated object;

FIGS. 7A and 7B are circuit diagrams showing example
configurations of an acceleration voltage-applying circuit;

FIG. 8 is a time chart showing an example configuration
25 for applying positive and negative acceleration voltages in
pulses; and

FIG. 9 is a perspective view showing the construction of
a beam source according to a second embodiment of the present

invention.

Best Mode for Carrying Out the Invention

A beam source according to preferred embodiments of the present invention will be described while referring to the accompanying drawings.

FIG. 1 is an explanatory diagram showing the overall construction of a processing apparatus employing a beam source according to a preferred embodiment of the present invention.

A beam source 10 comprises a discharge tube 11 and a plasma forming means (a coil 20 and the like) disposed external to the discharge tube 11. The plasma forming means converts gas introduced through a gas inlet 12 into plasma. The inside of the discharge tube 11 and an adjacent chamber 15 are evacuated to form a high vacuum using a turbo-molecular pump 18 and a rotary pump 19. An inductively coupled coil 20 is disposed around the discharge tube 11. A radio-frequency power source 21 supplies an RF power of 13.56 MHz, for example, to the coil 20 via a matching box 22 to convert gas introduced into the discharge tube 11 into plasma.

The coil 20 is a water-cooled pipe type coil, for example, having an external diameter of approximately 8 millimeters and is surrounded around the discharge tube 11 approximately two turns.

Charged particles including positive or negative ions from plasma formed in the discharge tube are accelerated, emitting an energy beam, such as an ion beam or a neutral particle beam, from an electrode 14 on the downstream end of the discharge tube 11 into the beam discharge chamber 15. A gas feed pipe 13 introduces a gas, such as SF₆, CHF₃, CF₄, Cl₂, Ar, O₂, N₂, and C₄F₈,

into the discharge tube 11, forming an energy beam, such as an ion beam or a neutral particle beam, from elements or molecules in this gas. The beam collimates in the chamber 15 and irradiates a sample 17 mounted on a sample support 16.

FIG. 2 shows the construction of the beam source according to the first embodiment of the present invention. The discharge tube 11 is cylindrically shaped and configured of a tube formed of quartz glass, ceramic, or the like. The discharge tube 11 is a hermetically sealed construction formed by the gas inlet 12 disposed on the upstream end of the discharge tube 11 for introducing gas therein, and the beam-emitting electrode 14 disposed on the downstream end of the discharge tube 11 and formed with a plurality of beam-emitting holes for emitting the beam formed in the discharge tube 11. Within the discharge tube 11 are disposed an upstream electrode 23 formed with a plurality of openings that enable the passage of gas through the upstream end, and a mesh electrode 24 comprising a thin plate formed with a plurality of openings. A means is provided for converting gas introduced between the upstream electrode 23 and middle mesh electrode 24 into plasma. In the present embodiment, this means is the RF coil 20 provided for forming inductively coupled plasma. A high frequency magnetic field is formed in the discharge tube 11 by supplying an RF current at, for example, 13.56 MHz from the power source 21. The gas introduced between the upstream electrode 23 and mesh electrode 24 is excited by this magnetic field and transformed into plasma. In addition to the ICP generating coil described above, it is also possible to employ an ECR, helicon wave plasma coil, electromagnetic coil,

microwaves, or the like to generate plasma. The plasma-generating device can use a frequency within the range from 1 MHz to 20 GHz and is not limited to 13.56 MHz.

The RF current supplied to the coil 20 generates a magnetic field in a plasma chamber 25 formed between the upstream electrode 23 and mesh electrode 24. The magnetic field couples with gas G introduced through the gas inlet 12 to form high-density plasma having an electron density of 10^{11} - $10^{12}/\text{cm}^3$. As shown in the diagram, the upstream electrode 23 and mesh electrode 24 are electrically connected by wiring 26 and maintained at approximately the same potential. As a result, the plasma formed in the chamber 25 between the upstream electrode 23 and mesh electrode 24 has approximately the same potential as that applied to the upstream electrode 23 and mesh electrode 24. For example, if the introduced gas is FS_6 , the input RF power is approximately 150 Watts. In the present embodiment, the diameter of the discharge tube 11 is 50 millimeters, but can also be set to 10-300 millimeters.

A wiring 27 is connected between the wiring 26, connecting the upstream electrode 23 and mesh electrode 24, and the beam-emitting electrode 14. An acceleration voltage-applying device 28 is connected to the wiring 27. In the example of FIG. 2, the acceleration voltage-applying device 28 accelerates positive ions near the mesh electrode 24 toward the beam-emitting electrode 14 by applying an accelerating energy in the form of a positive high voltage. In other words, the acceleration voltage-applying device 28 applies a potential different from the potential of the plasma formed in the chamber 25 across the

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mesh electrode 24 and beam-emitting electrode 14. In this state, charged particles such as positive and negative ions and electrons escaping through the mesh electrode 24 to the acceleration side are accelerated toward the beam-emitting electrode 14, pass through discharge holes 14a formed in the beam-emitting electrode 14, and are irradiated externally as a beam B. According to the construction of the beam source shown in FIG. 2, the distance between the mesh electrode 24 and beam-emitting electrode 14 can be set at an arbitrary value. Accordingly, since the accelerating distance can be set arbitrarily when using high-density plasma, it is possible to form a beam of high directivity and high density, while controlling the energy level of the beam.

FIG. 3 shows the relationship between electron density of the plasma and the sheath length. As shown in the diagram, the higher the plasma potential (applied voltage), the longer the sheath length. As the electron density decreases, the sheath length tends to increase. In a beam generating method using a plasma sheath for ion acceleration, the length of the sheath greatly influences directivity of the beam. In principle, it is possible to generate beams with high directivity using a longer sheath length. The electron temperature in the example of FIG. 3 is 1.4 eV.

When employing the direct-current discharge method described in the prior art, generally plasma potential from about 500 V to 5 kV at an electron density of approximately 10^9 – $10^{10}/\text{cm}^3$ is employed. In this case, it is easy to achieve a sheath length of 10 millimeters or more. On the other hand, an electron density

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of 10^{11} - $10^{12}/\text{cm}^3$ can be obtained by forming high-density plasma using RF discharge or the like, thereby obtaining a large quantity of accelerated ions, in other words, a high-density beam. However, often a low-energy beam less than about 500 V is required, which achieves a sheath length of 0.1-3 millimeters when using the potential difference with that sheath. On the other hand, the diameter of the discharge holes is normally set at 1 millimeter. Accordingly, the beam-emitting holes greatly influence distortion in the electric field along the sheath length when the sheath length, in other words the acceleration distance, is only about 0.1-3 millimeters. As a result, it is difficult to achieve acceleration with high directivity. However, when using a long sheath of approximately 10-30 millimeters in plasma formed by direct-current discharge or the like, described above, the effect of the beam-emitting holes on electric field distortion is smaller, making it possible to emit a beam with high directivity.

The present invention employs an electrode construction when using high-density plasma that enables beam emission with high directivity. In other words, the present invention solves the above problem by employing the mesh electrode 24 to partition the chamber 25, as shown in FIG. 2. This allows the distance between the mesh electrode 24 and beam-emitting electrode 14 to be set at an appropriate length. The mesh electrode 24 of the present embodiment employs a cross mesh having a wire thickness and width of 0.3 millimeters and a space between wires of 0.8 millimeters.

FIGS. 4A, 4B, and 4C show example formations of the mesh

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electrode. The mesh electrode can be configured by forming holes in a thin conductive sheet formed of metal, graphite, or the like, as shown in FIGS. 4A and 4C, or by metal wires woven together, as shown in FIG. 4B. The shape of the mesh electrode greatly affects the characteristics of the resulting beam and the processing characteristics on the object of irradiation. The mesh electrode 24 has a thickness no greater than 1 millimeter and preferably 0.1-0.5 millimeters. The mesh electrode 24 has a plurality of openings formed in the mesh, each having an open area ratio of 85% or less. Although the pattern of openings formed in the mesh is generally shaped like a checkerboard grid, as shown in the drawings, the mesh is not limited to this shape. The aspect ratio of the holes is 1 or less. Further, if the mesh is too thick, the amount of ion deactivation increases, thereby decreasing efficiency.

Beam diameter, directivity, and processing speed have the following relationships to the open area ratio in the mesh. As the open area ratio increases, the beam diameter increases, directivity drops, and processing speed increases. In contrast, as the open area ratio decreases, the beam diameter decreases, directivity increases, and the processing speed decreases. The resulting shapes of the target of beam processing are shown in FIG. 5. The resulting shape is sloped, as shown in FIG. 5A, when the open area ratio is too small. A suitable anisotropic etching, as shown in FIG. 5B, is achieved when the open area ratio is appropriate, but isotropic etching, as shown in FIG. 5C, results when the open area ratio is too large.

Similarly, when employing a relatively low energy beam

suitable for such micro-fabricating processes as deposition and etching, in other words with an ion accelerating voltage of 1 kV or less, an appropriate distance L exists between the mesh electrode and the beam-emitting electrode. In FIG. 6, the X-axis represents the distance between the mesh electrode and the beam-emitting electrode, while the Y-axis represents the processing speed on the object of irradiation. As shown in FIG. 6, a beam with good processing capacity can be achieved by setting a distance L of approximately 10-30 millimeters. The distance L should be at least 5 millimeters or greater since efficient acceleration cannot be achieved when the distance L is too small. Obviously, different processing speeds will occur by varying the distance L between the mesh electrode and beam-emitting electrode, even under the same conditions.

Further, the characteristics of the beam emitting from the discharge holes 14a of the beam-emitting electrode 14 greatly differ according to the length of the discharge holes 14a. Hence, the length of the discharge holes 14a must be selected according to the desired use of the beam source. A length of 1-5 times the hole diameter is appropriate for emitting electrons, ions, radicals, neutral particles having a low neutralization rate, and the like, creating a broad beam downstream from the beam-emitting holes. When the hole length is 5-10 times the hole diameter, the beam directivity improves, enabling localized irradiation of radical and electron beams. This length can achieve a neutralization rate for a neutral particle beam of about 30-70%. When the hole length is 10 times or greater that of the diameter, it is possible to obtain a beam of even greater

directivity and a neutral particle beam having a neutralization rate of about 70% or greater. In the present embodiment, the thickness of the beam-emitting electrode is 2 millimeters, while the ratio of hole diameter to length of the beam-emitting holes is preferably 2 or greater.

By setting the acceleration voltage-applying device 28 to a high negative voltage, the potential of plasma formed in the chamber 25 will have a high negative potential. If the beam-emitting electrode 14 is set to a zero potential, negative ions formed in the plasma can be accelerated to emit a negative ion beam. In this case, it is preferable to use a gas conducive to generating negative ions, such as O_2 , Cl_2 , SF_6 , CHF_3 , and C_4F_8 . When generating high-density plasma through high-frequency inductive coupling or the like using such gases, numerous negative ions are generated in the plasma, facilitating the formation of a negative ion beam. When using SF_6 gas in a beam source having the specifications described above, a positive ion beam capable of performing anisotropic processing is generated at an acceleration voltage of from +50 V to +1 kV. The processing speed of the beam source on a silicon substrate is 500 Å/min or greater. A negative ion beam is also generated at an acceleration voltage of from -50 V to -1 kV.

By connecting an acceleration voltage-applying device, as shown in FIG. 7A, that can be switched between a positive and negative voltage, it is possible to irradiate alternate negative and positive ion beams on a workpiece. By providing variable acceleration voltage, beams of different energy levels can be irradiated while varying the time of irradiation. It is also

possible to apply a pulse type positive and negative acceleration voltage using the device shown in FIG. 7B. With this configuration, a positive ion beam and negative ion beam can be irradiated alternately in pulses. When using a gas not conducive to generating negative ions, such as argon gas, an electron and positive ion beam can be emitted alternately. In the example shown in FIG. 8, a voltage of +300 V is applied for 20 milliseconds, followed by -50 V for 5 milliseconds. Then the voltages are repeatedly applied alternately.

Hence a positive ion beam having an energy of +300 eV is emitted from the beam source over an interval of 20 milliseconds. Next, a negative ion beam (or an electron beam) having energy of -5 eV is emitted for an interval of 5 milliseconds, and the process is repeated. When processing insulating materials such as glass and ceramics, a charge tends to build up on the surface of the materials. However, by alternately irradiating positive ions and negative ions (or electrons), high-precision etching or deposition processes can be performed on these materials while restraining the amount of surface charge. In the same way, energy can be varied in pulses. This method is not limited to irradiating positive and negative ions. It is also possible to irradiate in pulses beams having the same charge (for example positive ions), but having different energies. For example, the beam source can alternately irradiate 1-keV positive ion and 1-eV positive ion beams.

FIG. 9 shows a beam source according to a second embodiment of the present invention. Unlike the flat plate-like shaped shown in FIG. 2, the upstream electrode 30 in this case includes

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a cylindrically shaped portion. The larger surface area of this electrode 30 increases the area of contact with plasma formed in the chamber 25, thereby increasing the amount of charged particles reacting on the surface of the electrode and stabilizing the potential of the plasma. The remaining construction of the beam source according to the second embodiment is the same as the beam source shown in FIG. 2 and has the same operations.

An example application for energy beams emitted from the above beam source will be briefly described. Examples of energy beams include radical beams of particles from reactant gas capable of forming a deposition layer, and low-energy neutral particle beams. When using methane gas as the source gas for the energy beam source, a radical beam containing carbon (C) is formed, generating a suitable graphite, diamond-like carbon, or the like as an adhesive.

In addition to the methane gas mentioned above, the gas supplied to the energy beam source can be a gas including a metal such as tungsten fluoride, aluminum chloride, or titanium chloride or a carbon-type or hydrocarbon-type gas, such as methane, having C or C-H. With such a gas, it is possible to deposit a tungsten film, aluminum film, titanium film, graphite film, diamond-like carbon film, hydrocarbon-containing polymer film, or the like on the object of irradiation.

In the embodiment described above, an upstream electrode, mesh electrode, and beam-emitting electrode are disposed in planes parallel to one another within a cylindrical discharge tube. The discharge tube, however, need not be cylindrical in

shape, but can be elliptical or prismatic. The upper electrode does not necessarily have to be in a plane parallel to the other electrodes, providing the downstream mesh electrode and beam-emitting electrode are disposed parallel to each other.

5 As described above, the present invention can efficiently generate a high-density beam with high directivity from high-density plasma. Accordingly, the present invention provides a beam source capable of irradiating an energy beam, such as an ion beam or a neutral particle beam, which is suitable
10 for micro-fabrication of semiconductors, high-density storage media, micro-machines, and the like.

Industrial Applicability

The present invention can form an energy beam such as a
15 high-density neutral particle beam, ion beam, or the like having a relatively large diameter and good collimation. Accordingly, the present invention is suitable for use as an energy source for such processes as deposition, etching, or the like in data storage media, such as semiconductor ICs, hard disks or the like,
20 or in such micro-fabrication as micro-machining.

CLAIMS

1. A beam source comprising:

a discharge tube;

5 a gas inlet for introducing gas into the discharge tube;

three electrodes mounted in the discharge tube downstream
from the gas inlet, wherein the electrode on the upstream end
has a plurality of openings through which the gas can pass, the
middle electrode is a mesh-shaped electrode, and the electrode
10 on the downstream end is a beam-emitting electrode having a
plurality of beam-emitting holes and is disposed in a plane
parallel to the middle electrode;

plasma-generating means disposed between the two upstream
electrodes on the outside of the discharge tube for transforming
15 gas introduced into the discharge tube into plasma; and

voltage-applying means for accelerating the beam between
the two downstream electrodes and emitting the accelerated beam
from the downstream beam-emitting electrode.

20 2. A beam source as claimed in claim 1, wherein the two
electrodes on the upstream end have the same potential, while
the beam-emitting electrode on the downstream end has the same
potential as that of a chamber into which the beam is emitted.

25 3. A beam source as claimed in claim 1, wherein the two
electrodes on the downstream end are separated by a distance of
5 millimeters or greater, and preferably by a distance of 10-30
millimeters.

4. A beam source as claimed in claim 1, wherein each of
the beam-emitting holes formed in the beam-emitting electrode
on the downstream end has a length-to-diameter ratio of 2 or
5 greater.

5. A beam source as claimed in claim 1, wherein the
voltage-applying means applies a positive-negative pulse-type
voltage that alternately irradiates either positive ions and
10 negative ions or positive ions and electrons.

FIG. 1

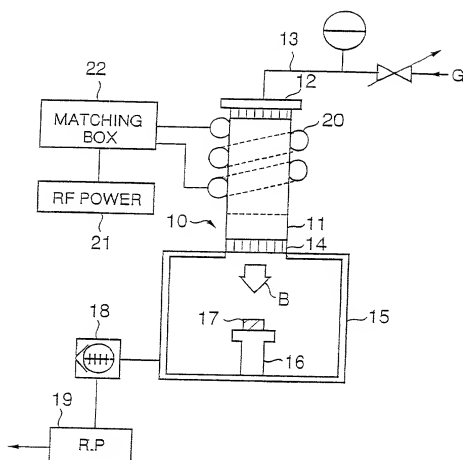


FIG. 2

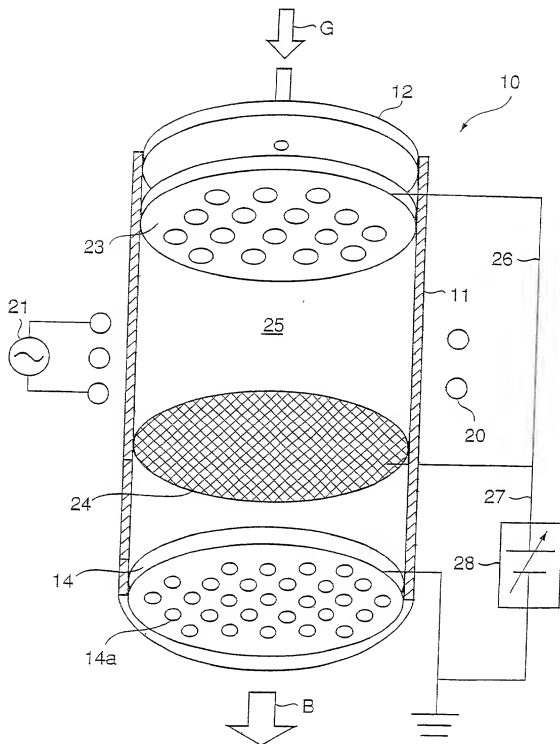


FIG. 3

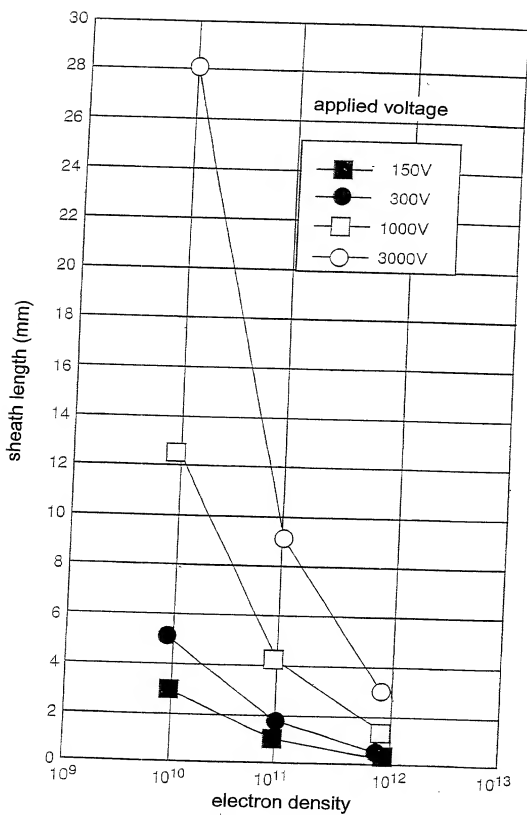


FIG. 4A

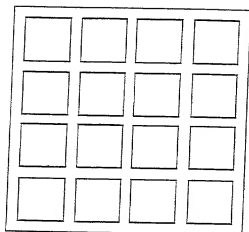


FIG. 4B

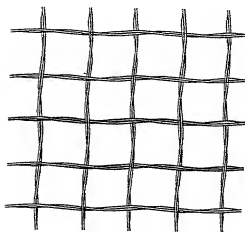


FIG. 4C

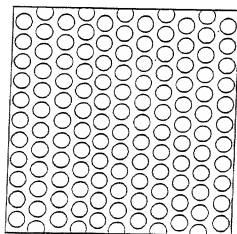


FIG. 5A FIG. 5B FIG. 5C

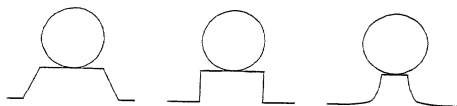


FIG. 6

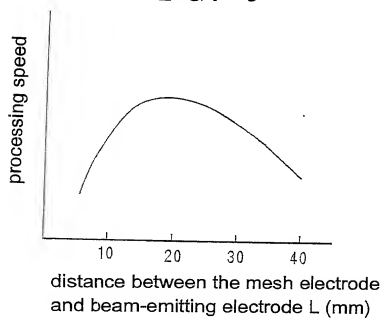
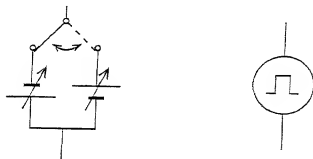
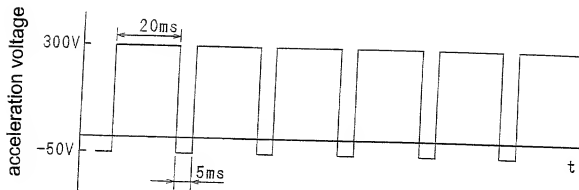


FIG. 7A FIG. 7B



6/7

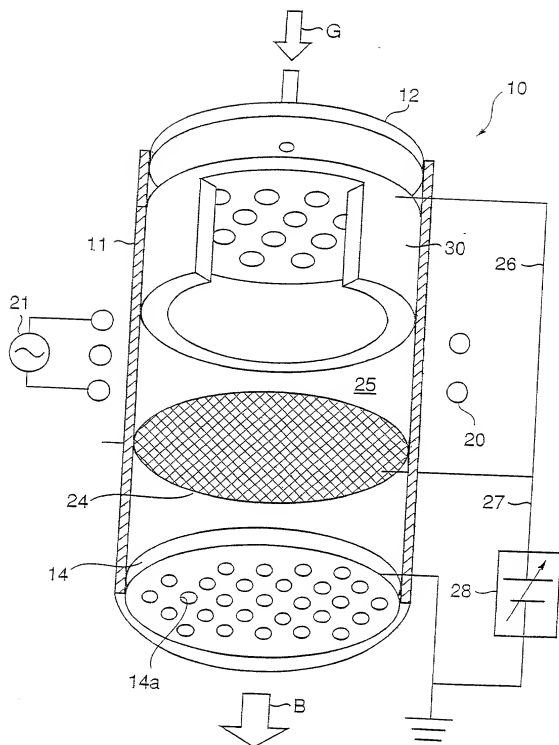
FIG. 8



201110/8005001

7/7

FIG. 9



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国際事務局(43) 国際公開日
2001年1月25日 (25.01.2001)

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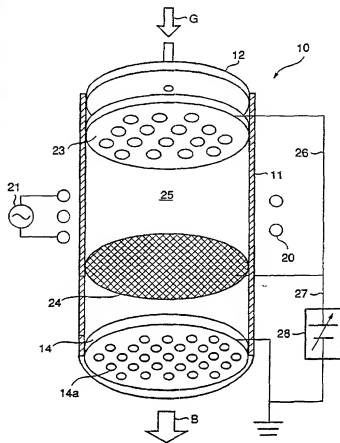
(10) 国際公開番号
WO 01/06534 A1

- (51) 国際特許分類: H01J 27/16, 37/08, H05H 3/00 (72) 発明者: および
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- (21) 国際出願番号: PCT/JP00/04744
- (22) 国際出願日: 2000年7月14日 (14.07.2000)
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- (26) 国際公開の言語: 日本語
- (30) 優先権データ:
特願平11/200989 1999年7月14日 (14.07.1999) JP (74) 代理人: 渡邊 勇, 外(WATANABE, Isamu et al.); 〒160-0023 東京都新宿区西新宿7丁目5番8号 GOWA 西新宿4階 Tokyo (JP).
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[続葉有]

(54) Title: BEAM SOURCE

(54) 発明の名称: ビーム源



(57) Abstract: The invention provides an efficient beam source that produces a directional, high-density energy beam having a relatively large size. The beam source comprises three electrodes, i.e., an upstream electrode (23) located downstream from a gas entrance port (12) in a discharge tube (11) and having a large number of holes through which gas passes, a meshed intermediate electrode (24), and a downstream electrode (14) having a large number of holes through which beams pass. Plasma means (20) for producing plasma is provided outside the discharge tube between the upstream and intermediate electrodes.

[続葉有]

E001

WO 01/06534 A1

Declaration for U.S. Patent Application

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

BEAM SOURCE

the specification of which is attached hereto unless the following is checked

☒ was filed on July 14, 2000 as United States Application Number or PCT International Application Number PCT/JP00/04744 and was amended on _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 (a) - (d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application for which priority is claimed:

(List prior foreign applications. See note A on back of this page)	<u>11-200989</u>	<u>Japan</u>	<u>14/07/1999</u>	Priority Claimed
	(Number)	(Country)	(Day/Month/Year Filed)	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
	<u> </u>	<u> </u>	<u> </u>	<input type="checkbox"/> Yes <input type="checkbox"/> No
	(Number)	(Country)	(Day/Month/Year Filed)	<input type="checkbox"/> Yes <input type="checkbox"/> No
	<u> </u>	<u> </u>	<u> </u>	<input type="checkbox"/> Yes <input type="checkbox"/> No
	<u> </u>	<u> </u>	<u> </u>	<input type="checkbox"/> Yes <input type="checkbox"/> No
	(Number)	(Country)	(Day/Month/Year Filed)	

(See note B on back of this page)

☐ See attached list for additional prior foreign applications

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

(List Prior U.S. Applications)

(Appln. Serial No.)	(Filing Date)	(Status: Patented, Pending, Abandoned)
(Appln. Serial No.)	(Filing Date)	(Status: Patented, Pending, Abandoned)
(Appln. Serial No.)	(Filing Date)	(Status: Patented, Pending, Abandoned)

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:



23850

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Title 18 of the United States Code, § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Full name of fifth inventor (given name, family name) _____
Inventor's signature _____ Date _____
Residence _____ Citizenship _____
Post Office Address _____

Full name of sixth inventor (given name, family name) _____
Inventor's signature _____ Date _____
Residence _____ Citizenship _____
Post Office Address _____

Full name of seventh inventor (given name, family name) _____
Inventor's signature _____ Date _____
Residence _____ Citizenship _____
Post Office Address _____